Lightweight Simulation Scripting with Proto

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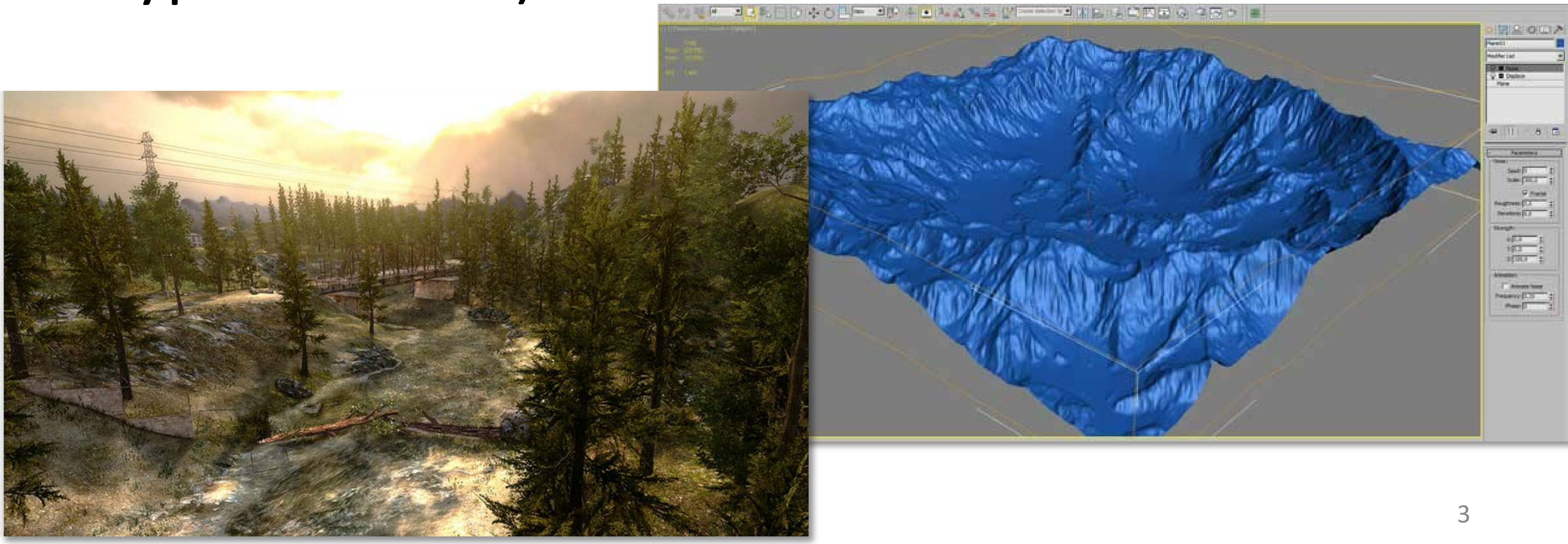
Serious Games

- Training
  - Reduce classroom lecture
  - Promote *active* learning
- US Navy VESSEL trainer

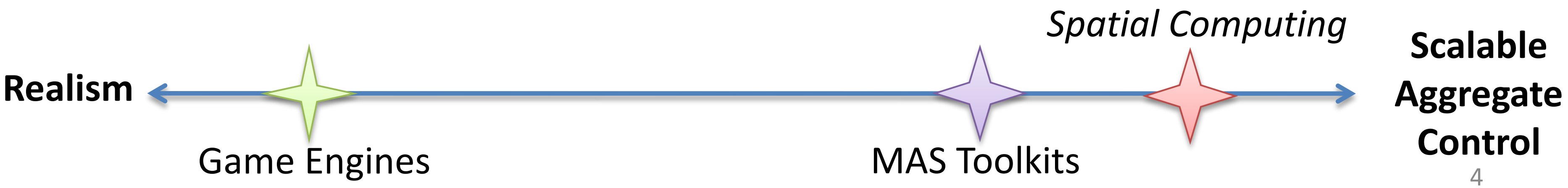
Game Engines

- Simplify creating complex, realistic simulations
- De-couples agent and terrain modeling and visualization (e.g., rendering, lighting, geo-typical terrain)



Problem

- Every game engine has a scripting API
- APIs allow control of all objects in the game
- Game Engines are limited in their support for quickly and easily scripting behaviors of large groups of autonomous agents
- Multi-Agent System (MAS) toolkits and simulators lack realism and features for spatial-aggregate programming



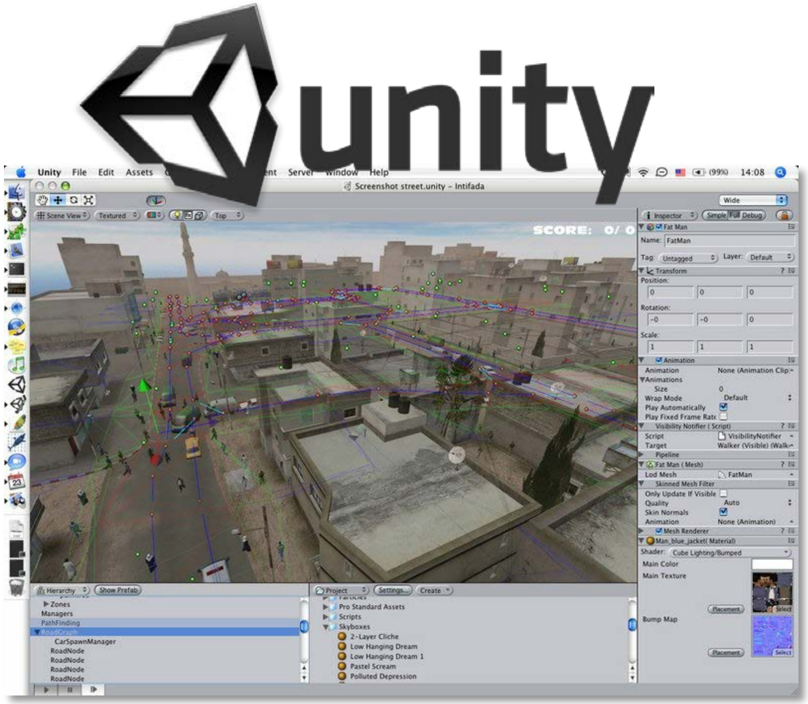
Spatial-Aggregate Programming

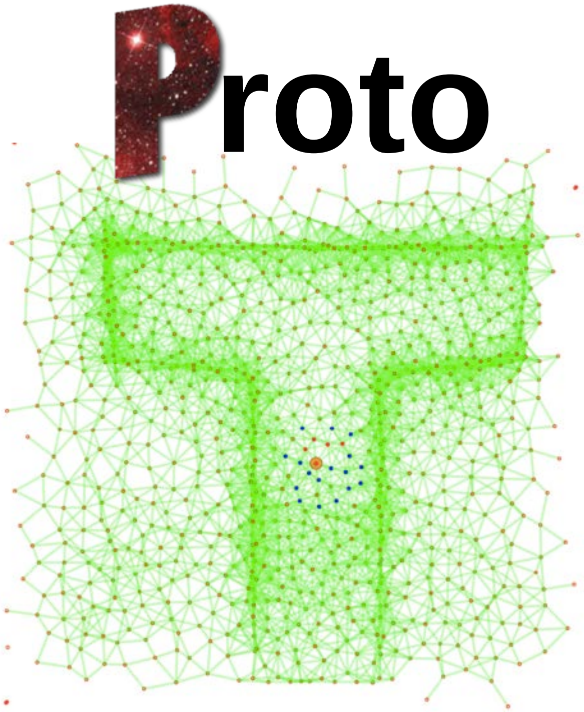
Shibuya Crossing, Tokyo

http://www.youtube.com/watch?v=P5vuWJft32g

Solution

- Combine modern game engine with **spatial** approach to scalable multi-agent behavioral scripting





Unity

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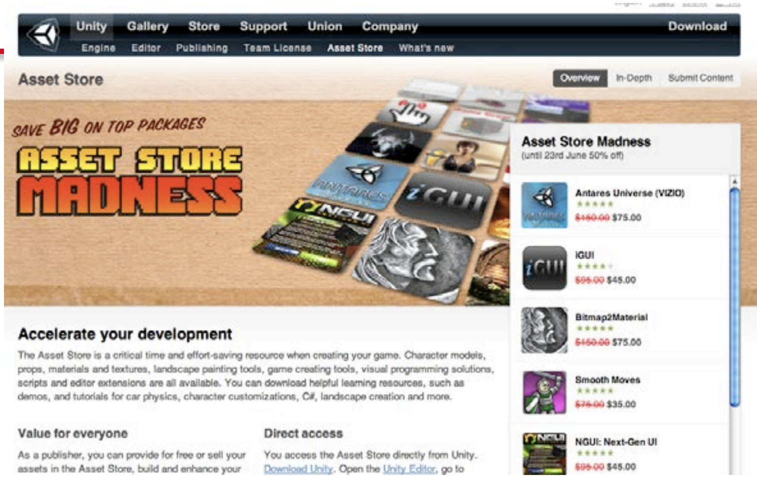


Asset Store

Asset Store Madness
(until 23rd June 50% off)

Antares Universe (VIZIO) ~~$160.00~~ $75.00

iGUI ~~$95.00~~ $45.00

Bitmap2Material ~~$150.00~~ $75.00

Smooth Moves ~~$75.00~~ $35.00

NGUI: Next-Gen UI ~~$95.00~~ $45.00

Accelerate your development

The Asset Store is a critical time and effort-saving resource when creating your game. Character models, props, materials and textures, landscape painting tools, game creating tools, visual programming solutions, scripts and editor extensions are all available. You can download helpful learning resources, such as demos, and tutorials for car physics, character customizations, C#, landscape creation and more.

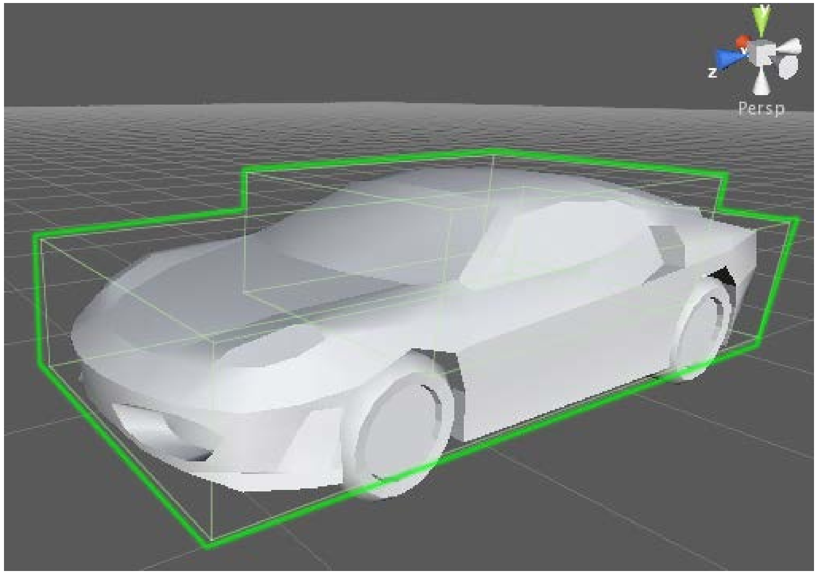
Value for everyone

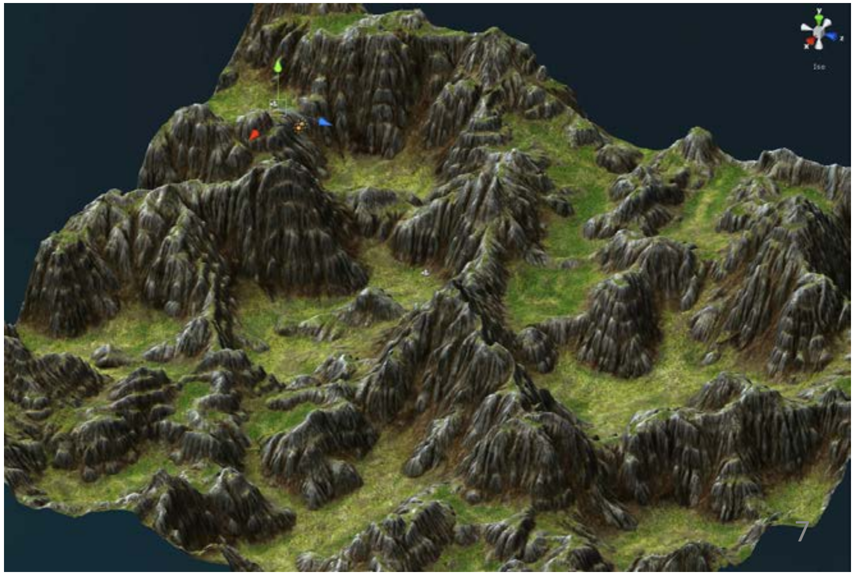
As a publisher, you can provide for free or sell your assets in the Asset Store, build and enhance your

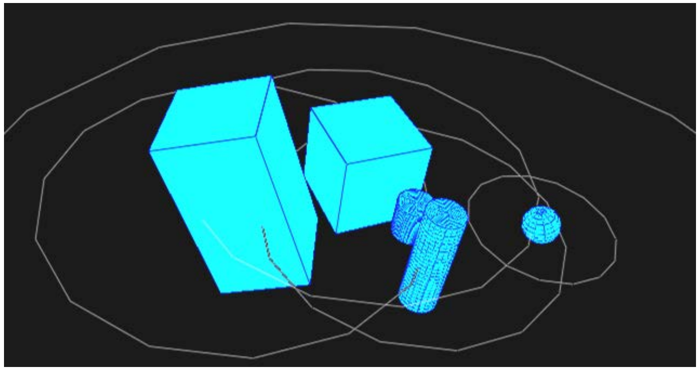
Direct access

You access the Asset Store directly from Unity. Download Unity. Open the Unity Editor, go to

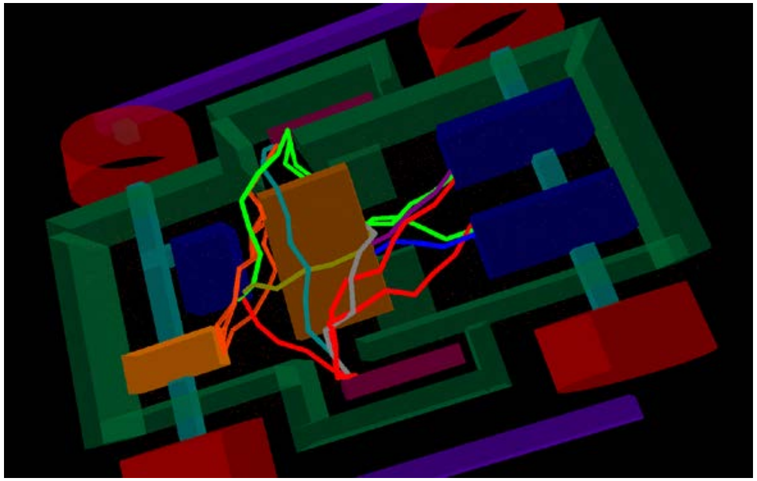
- What is Unity?
- Why Unity?
  - Realistic physics simulator
  - Simple/Realistic terrain modeling
  - Online market for “assets”

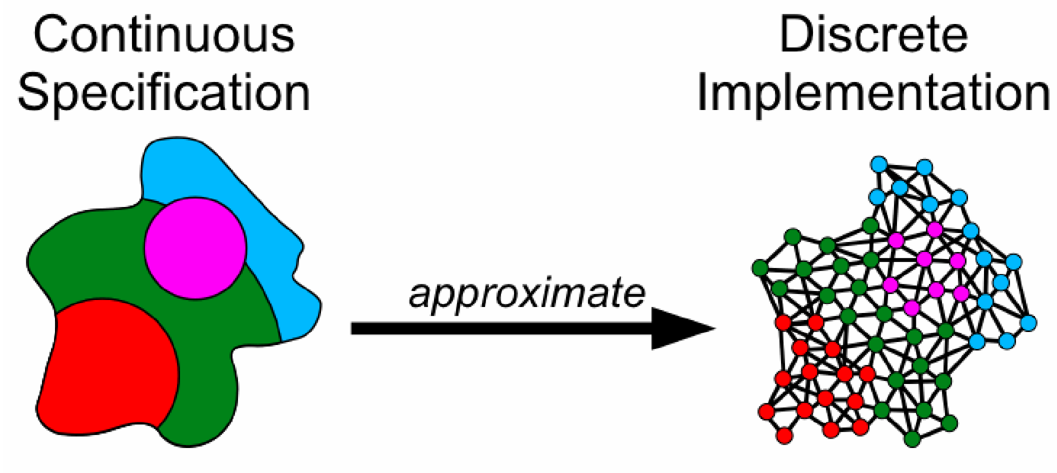






- What is Proto?
- Why Proto?
  - Global-to-local compiler
  - Extensible VM / Simulator Design



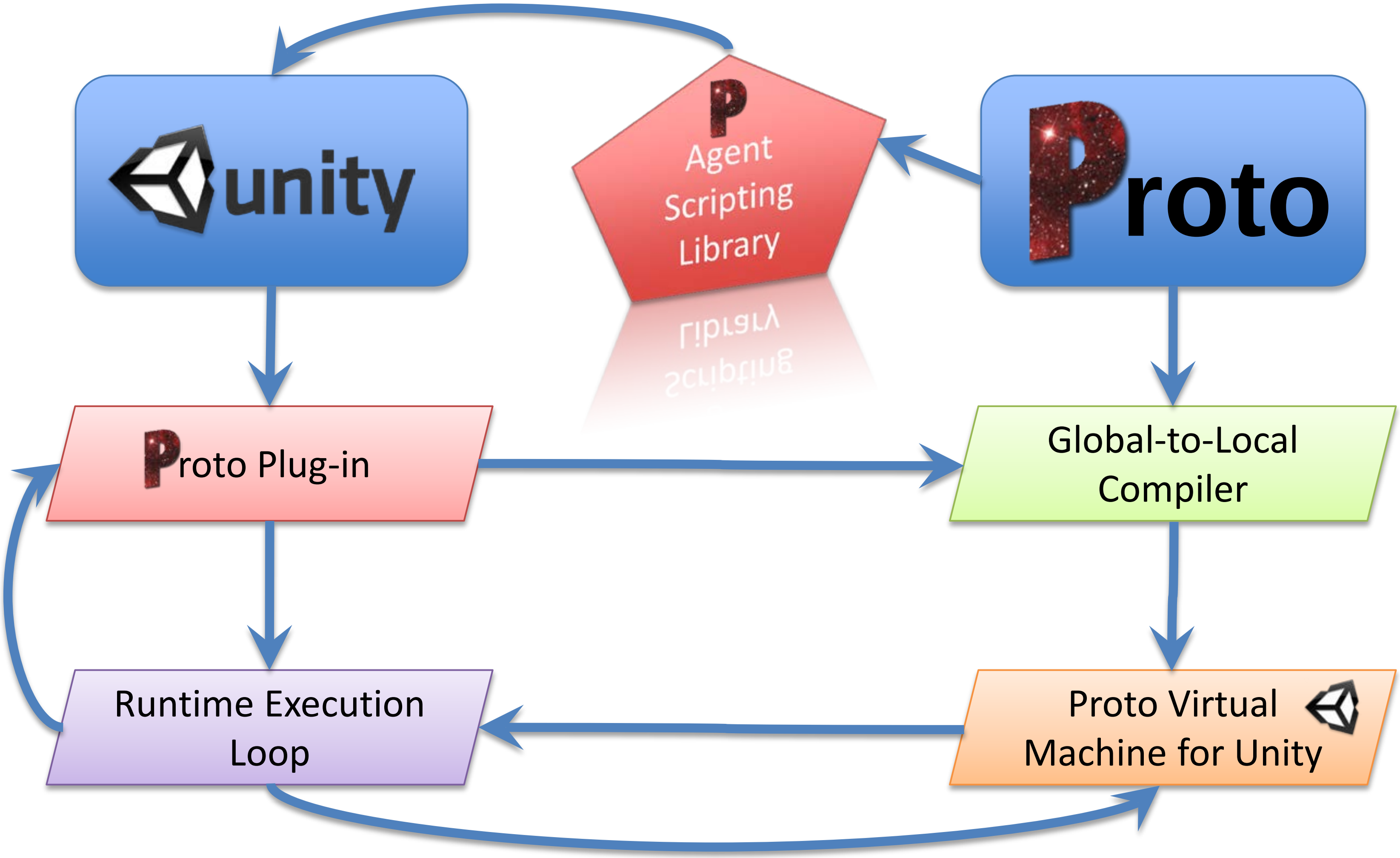


Approach

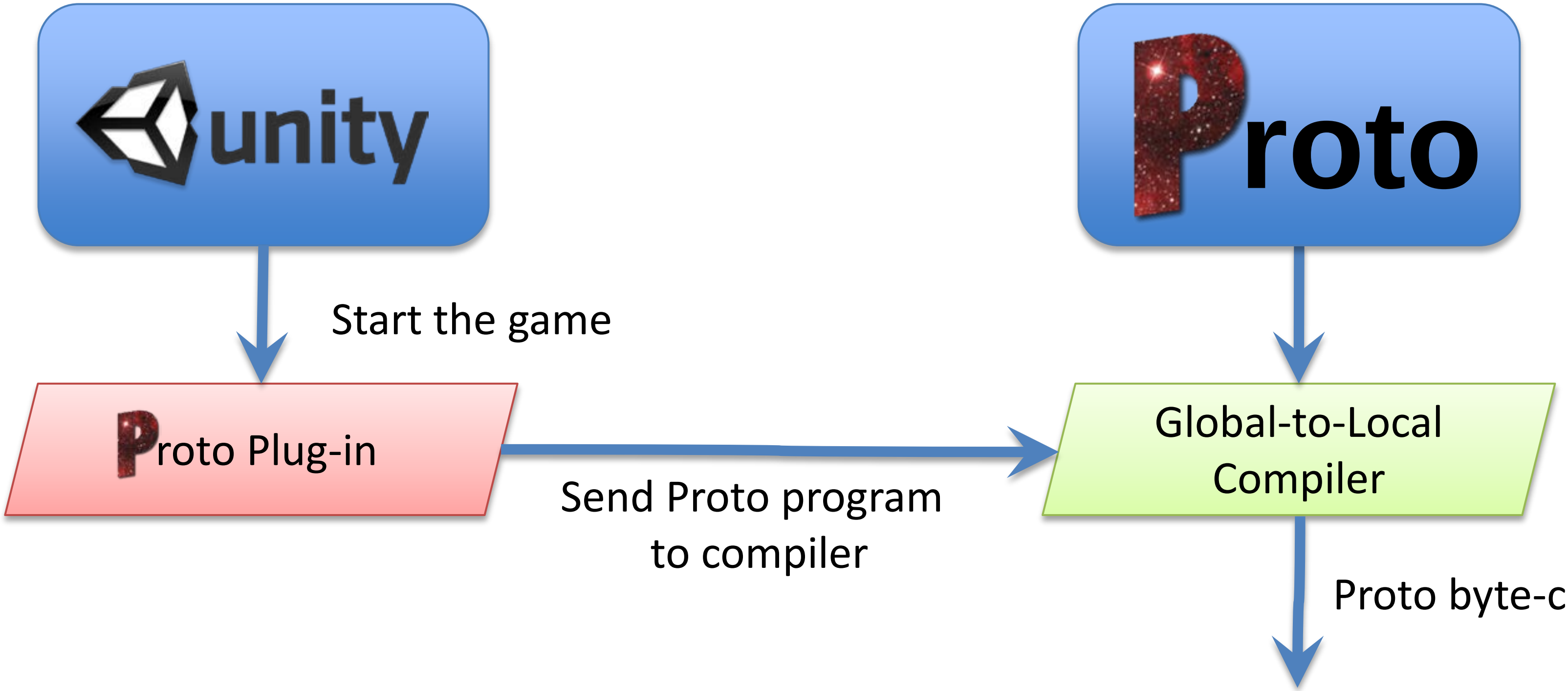
- Proto’s global-to-local compiler & VM
- Unity’s simulation environment
- Novel agent scripting library:
  - Group behavior primitives
  - Imperative-style scripting

unity
P
Agent
Scripting
Library
Proto

Architecture

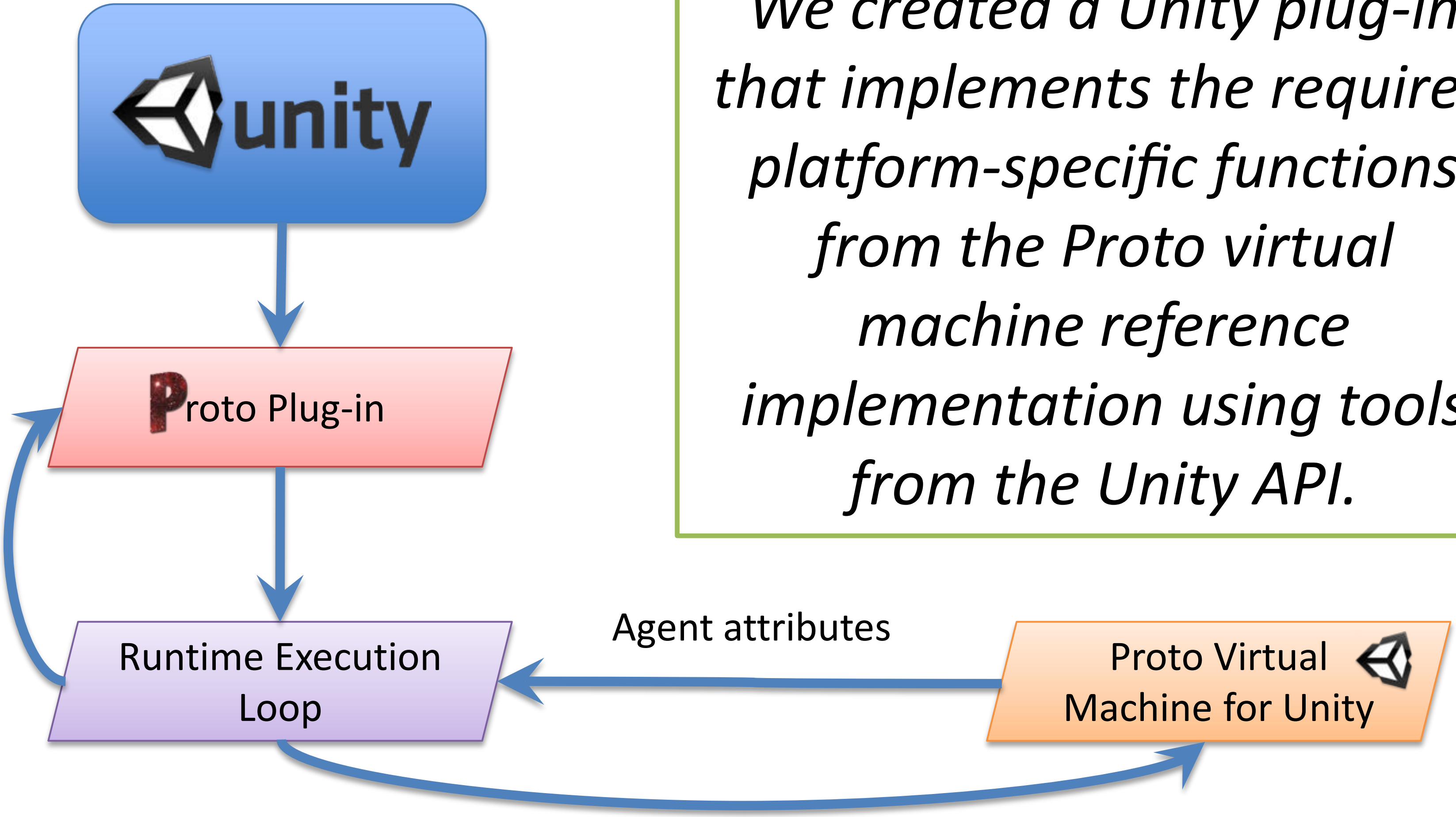


Invoking the Proto Compiler



We designed a Unity plug-in for Proto that invokes Proto’s compiler, which in-turn creates byte-code to be executed by the virtual machine(s).

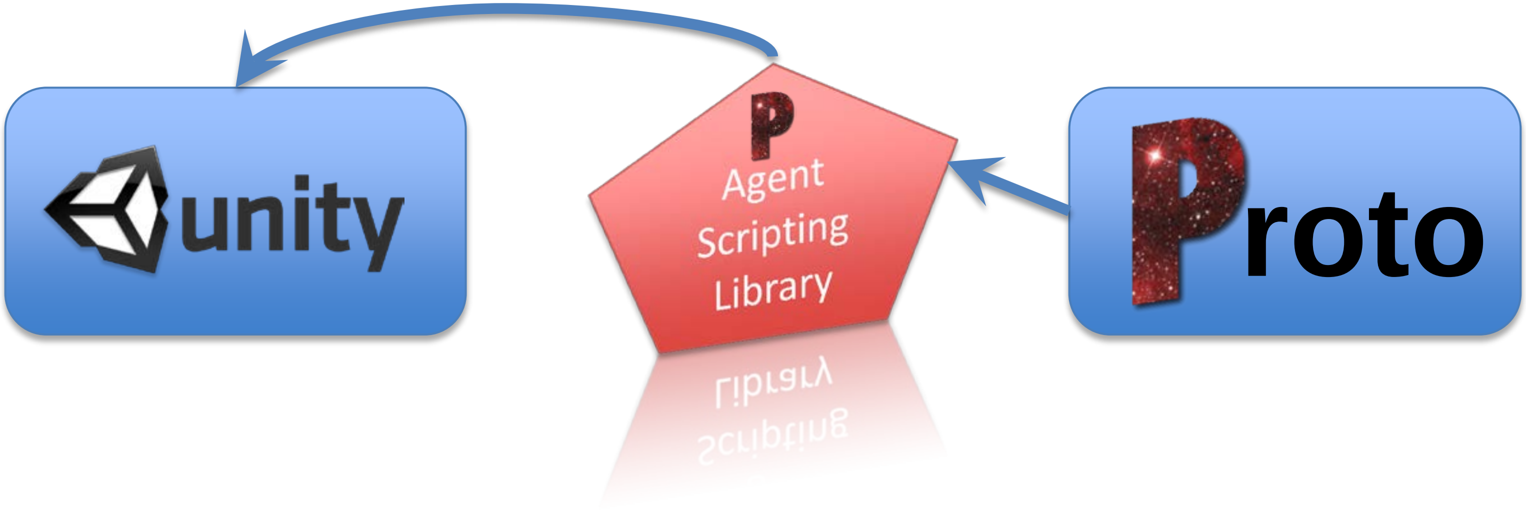
A Proto VM Implementation for Unity



We created a Unity plug-in that implements the required platform-specific functions from the Proto virtual machine reference implementation using tools from the Unity API.

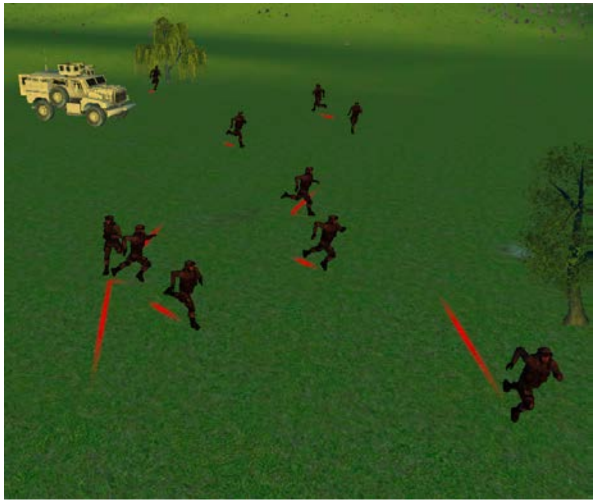
Temporal update, environmental changes

Agent Scripting Library

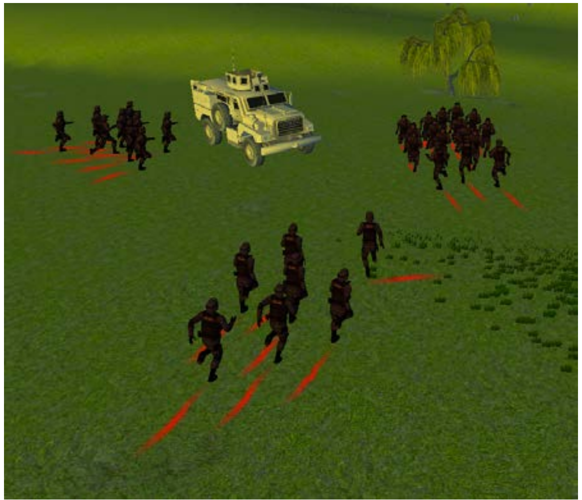


We created an agent scripting library that extends the Proto language with group behavior primitives and imperative-style macros.

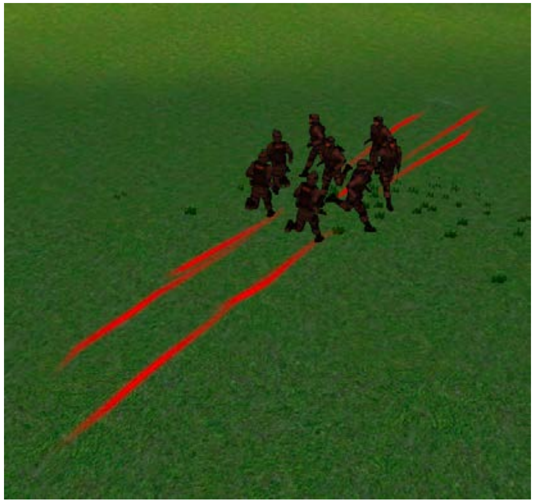
Group Behavior Primitives



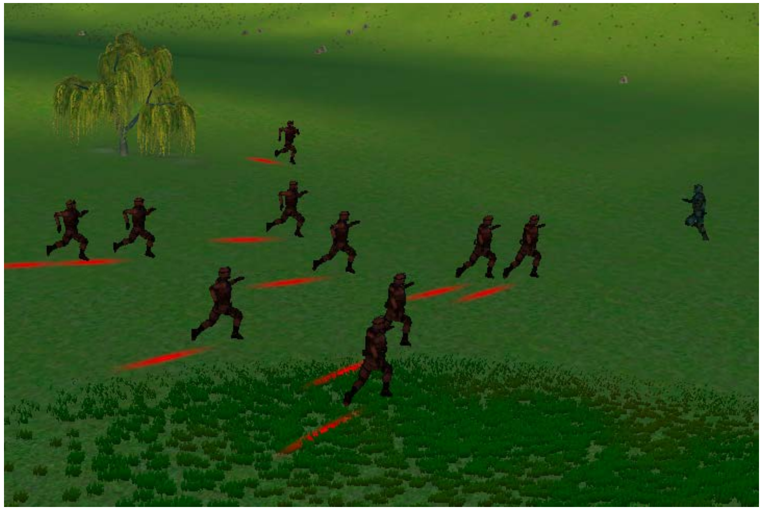
Random Walk



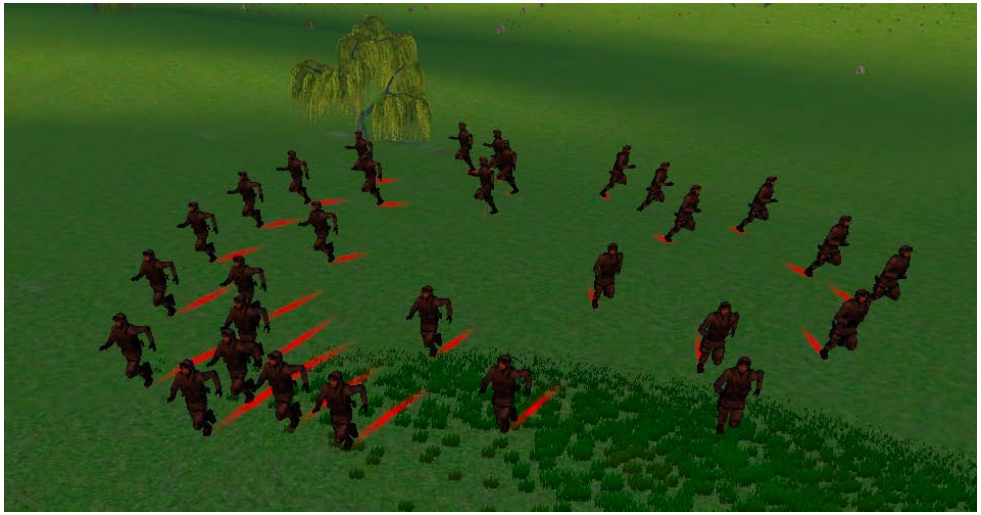
Flock / Flock-to



Cluster-by



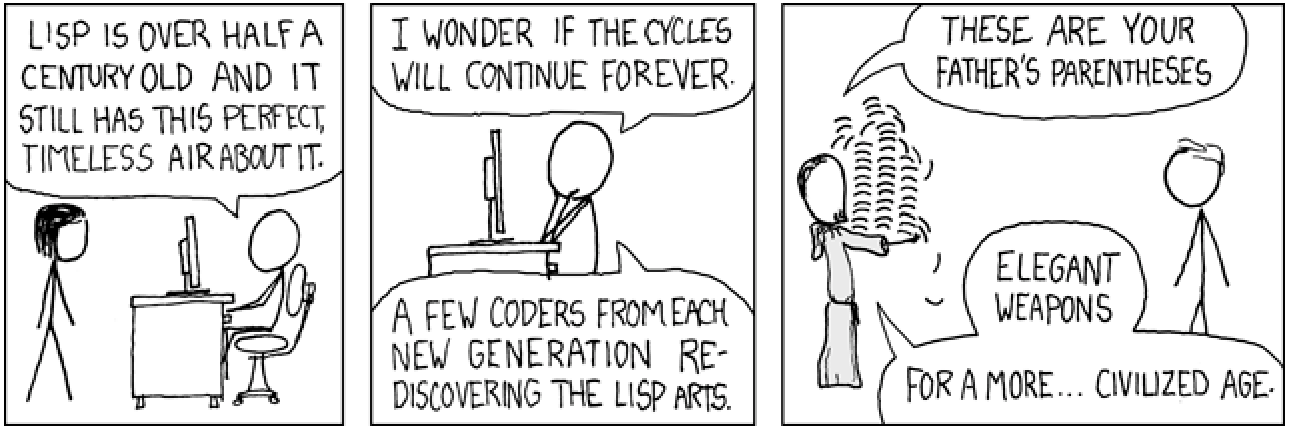
Toward



Disperse / Scatter

Imperative-Style Agent Scripting

- Proto is a pure-functional language based on LISP.
- Doesn’t map well to the typical agent scripting user’s imperative approach.


LISP IS OVER HALF A CENTURY OLD AND IT STILL HAS THIS PERFECT, TIMELESS AIR ABOUT IT.
I WONDER IF THE CYCLES WILL CONTINUE FOREVER.
A FEW CODERS FROM EACH NEW GENERATION RE-DISCOVERING THE LISP ARTS.
THESE ARE YOUR FATHER'S PARENTHESES
ELEGANT WEAPONS
FOR A MORE... CIVILIZED AGE.

Imperative-Style Agent Scripting

- Macro functionality added to Proto
- Added macros to make Proto read more sequentially, event-driven, and/or behaviorally

```
(def red-advance (red-team blue-team)
     (group-case
          (behavior-of red-team                ;; Red team behavior:
               (where in-group
                    (flock-to (tup 0 0)))      ;; go to Blue starting location
          (behavior-of blue-team                         ;; Blue team behavior:
               (on-trigger (can-see red-team)            ;; when Red is near...
                    (scatter (away-from red-team)))      ;; flee from Red!
          (default (tup 0 0))))))
```

Agent Scripting Library

```
(group-case
      (behavior-of MEMBERSHIP-TEST BEHAVIOR
      (behavior-of MEMBERSHIP-TEST BEHAVIOR
      …
      (default BEHAVIOR)…)))
```

```
(where TEST BEHAVIOR)
```

```
(priority-list
      (priority NAME TEST BEHAVIOR
      (priority NAME TEST BEHAVIOR
      …)))
```

```
(on-trigger TRIGGER BEHAVIOR)
```

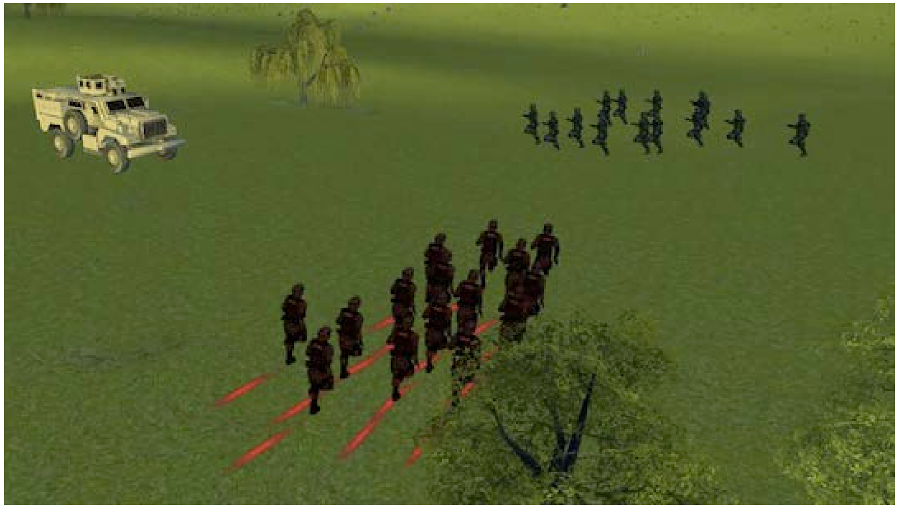
```
(sequence
      ([stage|group-stage] NAME ACTION TERMINATION
      ([stage|group-stage] NAME ACTION TERMINATION
      …
      [end-sequence|repeat])…))
```

Functional composition still applies!

Just a sampler... More to come!

Example: Advance & Flee!

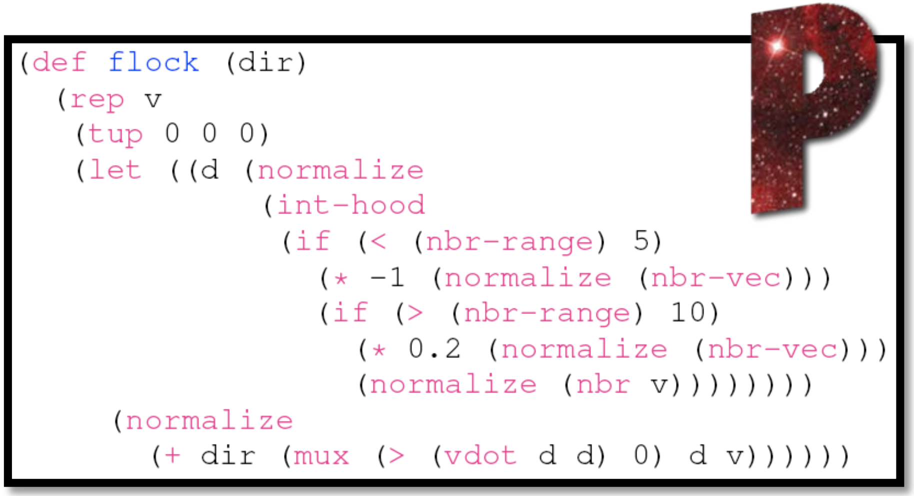
```
(def red-advance (red-team blue-team)
     (group-case
          (behavior-of red-team                    ;; Red team behavior:
               (where in-group
                    (flock-to (tup 0 0)))          ;; go to Blue starting location
          (behavior-of blue-team                             ;; Blue team behavior:
               (on-trigger (can-see red-team)                ;; when Red is near...
                    (scatter (away-from red-team)))          ;; flee from Red!
          (default (tup 0 0))))))
```



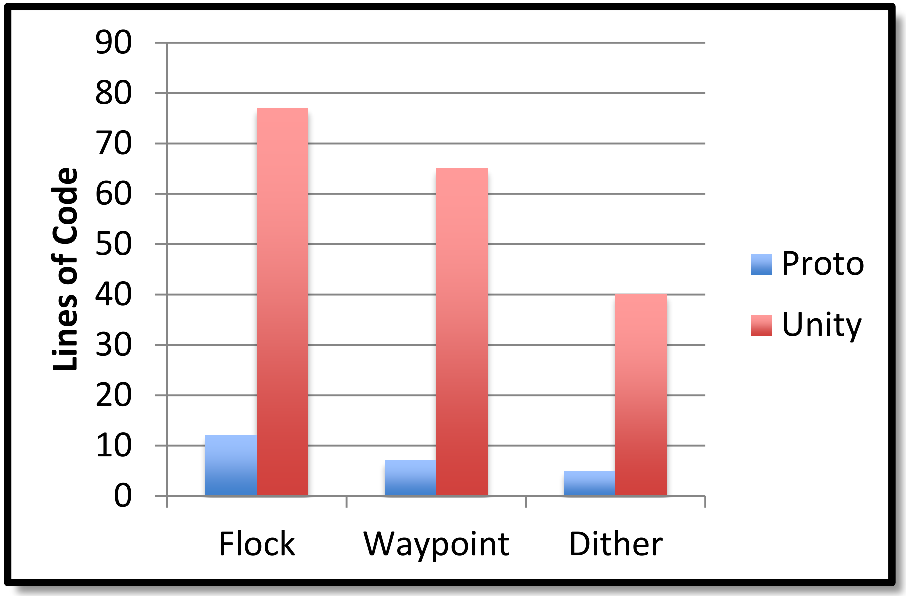
Example: Deploy

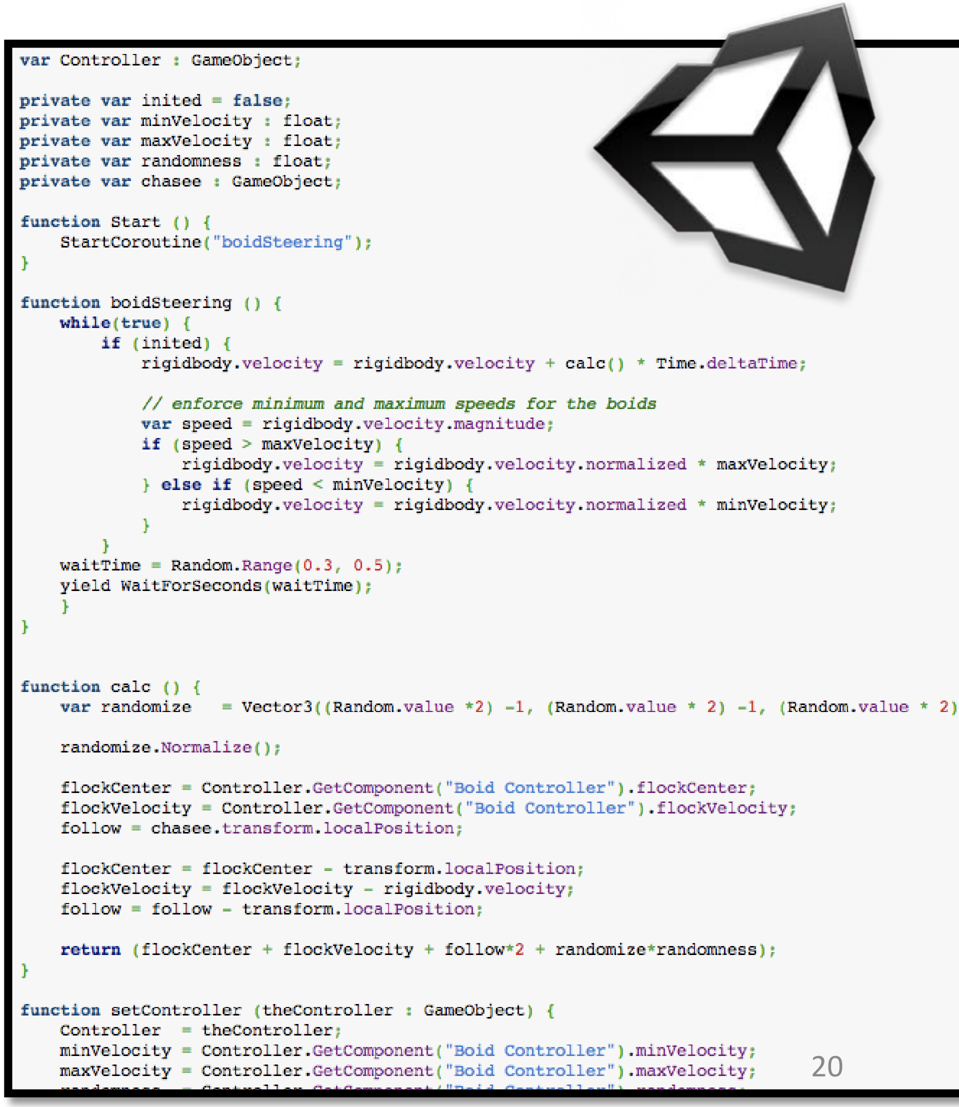
```
(def deploy (squadID)
  (sequence
   (stage leave-vehicle                  ;; First stage:
    (flock (tup -1 0 0))                   ;; move left...
    (timeout 20)                           ;; ... for twenty seconds.
   (stage group-by-squad                 ;; Second stage:
    (cluster-by squadID)                   ;; group into squads...
    (timeout 50)                           ;; ... for fifty seconds.
   (stage deploy-to-destination          ;; Third stage:
    (group-case                  ;; Each squad goes to a different location:
     (behavior-of (= squadID 0)            ;; First squad ...
      (flock-to (tup 50 100))              ;; ... goes to (50, 100)
     (behavior-of (= squadID 1)            ;; Second squad ...
      (flock-to (tup -200 0))              ;; ... goes to (-200, 0)
     (behavior-of (= squadID 2)            ;; Third squad ...
      (flock-to (tup -100 -100))           ;; ... goes to (-100, -100)
     (default (tup 0 0))))))
   ongoing                          ;; Sequence doesn't end or repeat
  end-sequence)))))
```

Code Comparison



```
(def flock (dir)
  (rep v
   (tup 0 0 0)
   (let ((d (normalize
             (int-hood
              (if (< (nbr-range) 5)
                (* -1 (normalize (nbr-vec)))
                (if (> (nbr-range) 10)
                  (* 0.2 (normalize (nbr-vec)))
                  (normalize (nbr v))))))))
     (normalize
       (+ dir (mux (> (vdot d d) 0) d v))))))
```





```
var Controller : GameObject;

private var inited = false;
private var minVelocity : float;
private var maxVelocity : float;
private var randomness : float;
private var chasee : GameObject;

function Start () {
    StartCoroutine("boidSteering");
}

function boidSteering () {
    while(true) {
        if (inited) {
            rigidbody.velocity = rigidbody.velocity + calc() * Time.deltaTime;

            // enforce minimum and maximum speeds for the boids
            var speed = rigidbody.velocity.magnitude;
            if (speed > maxVelocity) {
                rigidbody.velocity = rigidbody.velocity.normalized * maxVelocity;
            } else if (speed < minVelocity) {
                rigidbody.velocity = rigidbody.velocity.normalized * minVelocity;
            }
        }
    waitTime = Random.Range(0.3, 0.5);
    yield WaitForSeconds(waitTime);
    }
}


function calc () {
    var randomize   = Vector3((Random.value *2) -1, (Random.value * 2) -1, (Random.value * 2)

    randomize.Normalize();

    flockCenter = Controller.GetComponent("Boid Controller").flockCenter;
    flockVelocity = Controller.GetComponent("Boid Controller").flockVelocity;
    follow = chasee.transform.localPosition;

    flockCenter = flockCenter - transform.localPosition;
    flockVelocity = flockVelocity - rigidbody.velocity;
    follow = follow - transform.localPosition;

    return (flockCenter + flockVelocity + follow*2 + randomize*randomness);
}

function setController (theController : GameObject) {
    Controller  = theController;
    minVelocity = Controller.GetComponent("Boid Controller").minVelocity;
    maxVelocity = Controller.GetComponent("Boid Controller").maxVelocity;
    randomness  = Controller.GetComponent("Boid Controller").randomness;
```

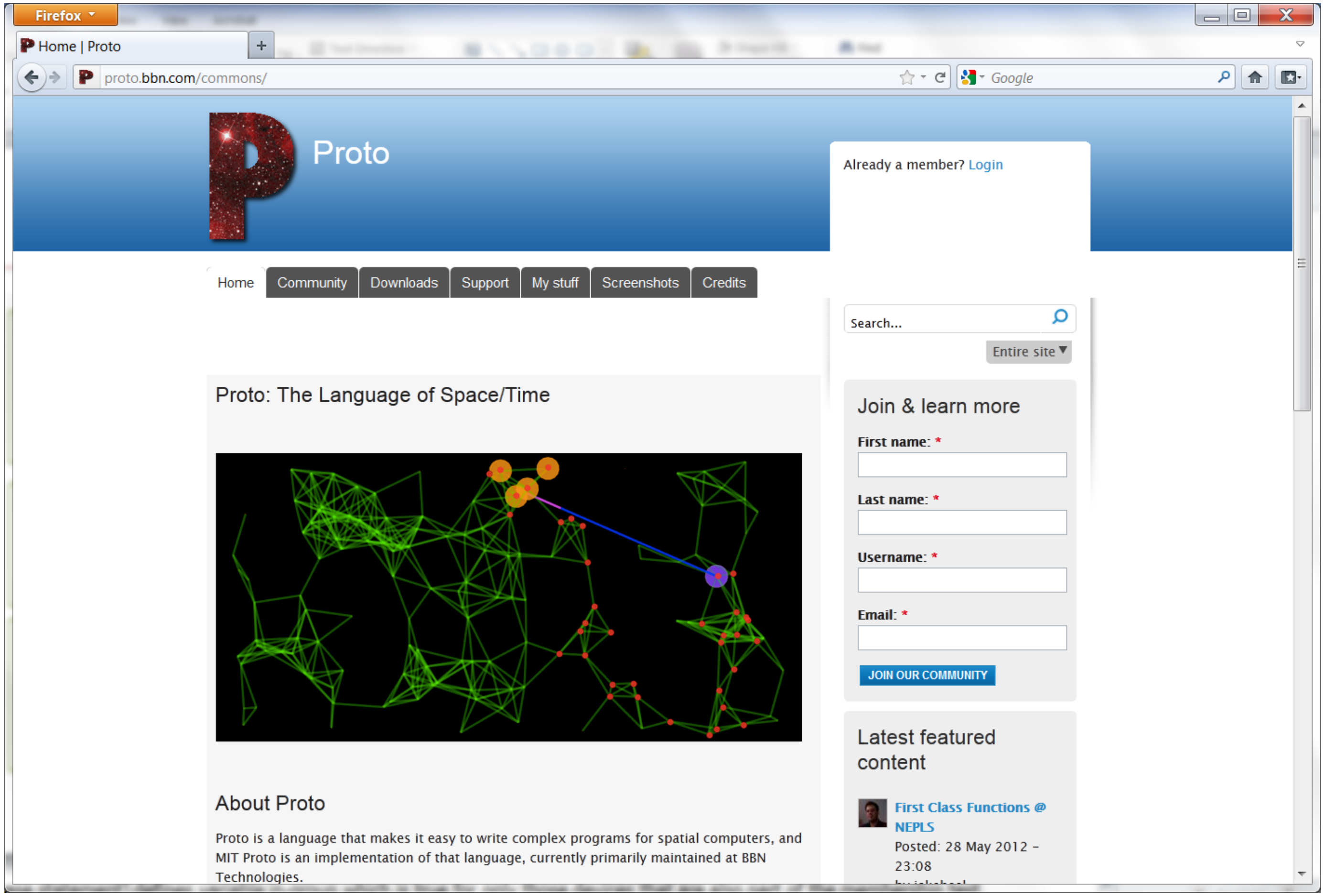
Benefits

- Scalable
  - Supports large numbers of agents
  - Scripts remain constant with dynamic numbers of agents
- Lightweight
  - Small memory and CPU profile
- Realistic movement – agents are affected by their environment (e.g., collision, gravity, etc.)
- Robust to behavioral changes – both during programming and during game-play

Future Work

- Proto Plug-ins for Unity-specific operators / controls
  - Line-of-sight (including terrain obstacles)
  - Operator feedback (e.g., “Agent can’t run at 5 mph in that direction because it would be up a hill.”)
- Adding to group behavior primitives and agent scripting library

Join the Proto Community



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Proto: The Language of Space/Time

About Proto

Proto is a language that makes it easy to write complex programs for spatial computers, and MIT Proto is an implementation of that language, currently primarily maintained at BBN Technologies.

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Last name: *

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